Incidence of Parasitoids and Parasitism of *Bemisia tabaci* (Homoptera: Aleyrodidae) in Numerous Crops

ALVIN M. SIMMONS,[1] SHAABAN ABD-RABOU,[2] AND GLORIA S. MCCUTCHEON[3]

USDA–ARS, U.S. Vegetable Laboratory, Charleston, SC 29414

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ABSTRACT Understanding the relationship of parasitoids with their insect hosts and crop plants is needed to develop good management strategies for *Bemisia tabaci* (Gennadius), a whitefly pest. The abundance and establishment of parasitoids of *B. tabaci* B-biotype were tested with taxonomically diverse plants in the greenhouse (7 plant species) and in the field (16 plant species in Egypt). Greenhouse tests were conducted on plants free of whitefly nymphs to avoid this influence on parasitoid behavior, and field tests were conducted in crops with feral populations of *B. tabaci*. In the greenhouse, the parasitoid, *Encarsia pergandiella* Howard, was most abundant on *Vigna unguiculata* (L.) Walpers, followed by *Gossypium hirsutum* L. The propensity for this parasitoid to forage on the bottom leaf surface compared with the top surface varied among crops (45–90% were on the bottom leaf surface) and over time (≈50% were on the bottom leaf surface around sunrise, whereas ≈90% were on the bottom surface by mid-day). Inundative releases of laboratory-reared parasitoids, *Eretmocerus mundus* (Mercet), into field crops increased parasitization rates in all crops tested. Some crops (e.g., two *Brassica* species and *V. unguiculata*) were more conducive to parasitism of *B. tabaci* than other crops (e.g., *Cucumis sativus* L. and *Lycopersicon esculentum* Miller). Findings from this research may be useful in the enhancement and conservation of parasitoids of *Bemisia.*

KEY WORDS *Bemisia tabaci*, *Encarsia*, *Eretmocerus*, biocontrol, vegetable, whitefly

THE SWEETPOTATO WHITEFLY B-biotype, *Bemisia tabaci* (Gennadius), feeds on and damages numerous row, vegetable, and ornamental crops. It is a serious pest on a global scale, notably in temperate and tropical climates. Treatment with insecticides is currently the main method of control. However, researchers and growers are interested in optimizing noninsecticidal methods, such as host plant resistance and beneficial organisms, to use in whitefly management schemes.

Several species of hymenopterous parasitoids attack *B. tabaci* (Gerling 1986, Lopez-Avila 1986, Polaszek et al. 1992). These consist primarily of *Eretmocerus* spp., *Encarsia* spp., and, to a lesser degree, *Amitis* spp. (Hoelmer 1995, Joyce et al. 1999). *Encarsia pergandiella* Howard is indigenous to the southeastern U.S.A. and commonly parasitizes *B. tabaci*, but its abundance can vary among locations and over time (McAuslane et al. 1993, McAuslane et al. 1994, Riley and Ciomperlick 1997, Schuster et al. 1998, Simmons 1998, Simmons and Jackson 2000). Likewise, the abundance of *Bemisia* spp. on host plants can vary dramatically, and may be affected by factors such as climate and plant species (van Lenteren and Noldus 1990, Simmons 1994, 1999, Simmons and Elsey 1995, Simmons et al. 2000).

Biological control of field populations of *Bemisia* spp. has been attempted by the introduction of exotic parasitoids and conservation of exotic and endemic parasitoids (Goolsby et al. 1998, Henneberry et al. 1998). One of the parasitoid species of *B. tabaci* that has shown promise for inundative field release is *Eretmocerus mundus* (Mercet) (Goolsby et al. 1998). An understanding of the interactions of parasitoids with host plants of *Bemisia* spp. could aid in developing approaches to optimize benefits from parasitoids in pest management. Useful approaches may include conservation, enhancement, and augmentation of beneficial parasitoids. Thus, information is needed for important native and exotic parasitoids of *Bemisia* spp. This study was conducted to determine the influence of taxonomically diverse vegetable and other agronomic plant species on incidence of whitefly-associated parasitoids, and to test for an increase in parasitism after inundative parasitoid releases.

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[1] U.S. Vegetable Laboratory, USDA, Agricultural Research Service, 2875 Savannah Highway, Charleston, SC 29414.

[2] German Foundation for International Development/Food and Agriculture Development Center, Eilenburger Strasse 14, D-04509 Zschotau/Leipzig, Federal Republic of Germany.

[3] Department of Entomology, Clemson University, Coastal Research and Education Center, 2865 Savannah Highway, Charleston, SC 29414.

Materials and Methods

Parasitoid Abundance Among Plant Species. Seven species representing a diversity of agricultural crops were established in 15.2-cm green plastic containers in a whitefly-free greenhouse, and were maintained without pesticides. The plant species included: *Cucumis melo* L., cantaloupe, 'Top Mark'; *Brassica oleracea* variety *acephala* de Condolle, collard, 'Georgian'; *Gossypium hirsutum* L., cotton, 'Deltapine 90'; *Vigna unguiculata* (L.) Walpers, cowpea, 'Mississippi Silver'; *Capsicum annuum* L., bell pepper, 'Keystone'; *Glycine max* Merrill (L.), soybean, 'Hagood'; and *Lycopersicon esculentum* Miller, tomato, 'Homestead.' Multiple plantings were made to obtain plants at the 1 to 2 leaf stage for each plant species. The unifoliate stage was used for *V. unguiculata* and *G. max.* Five containers with single plants of each of the seven plant species were placed on a table in a greenhouse containing an open colony of a parasitoid, *E. pergandiella*, reared on *B. tabaci.* The whiteflies in the colony originated from a field of *Ipomoea batatas* L., sweetpotato, in 1992 and the colony was supplemented annually with feral populations from *I. batatas* to maintain genetic diversity. The insects were reared on assorted vegetables, then reared on the above test plants for two months before the first test. This was one of two whitefly colonies established in 1992, and this colony was invaded by native *E. pergandiella* in 1994. The parasitoids persisted in the colony since that time. The 35 test plants were arranged in a completely randomized design on a single table, and spaced 25 cm apart. The test plants were ≈1 m away from adjacent tables containing infested plants. Additional infested plants were placed near the ends of the same table as the test plants, and ≈1 m from the test plants.

Over 4 consecutive days, the numbers of parasitoids on the top and bottom leaf surfaces of each plant species were recorded by direct observations. On each day, the number of parasitoids was counted on each leaf at 0.5, 2.5, 4.5, and 6.5 h postsunrise. At the end of each of the 4 observational periods during each day, sun-exposed ambient temperature was measured at leaf height and recorded. Five trials, each consisting of four days of observations, were conducted for all plant species, but three plants of *G. hirsutum* were not tested in the first trial because they were not the correct leaf stage. Data were collected from 27 April to 4 June in 1998. After the last observation on the fourth day of each trial, the leaf area for each plant was measured from detached leaves using a leaf area meter (model 3000; LI-COR, Lincoln, NE). Because of some changes in leaf area within a trial, the number of parasitoids per unit leaf area was only determined for the last day of each trial. No counts of parasitoids or leaf area data were made on leaves that emerged between the first and fourth day of the observations.

Additional observations were made in a dual choice test on the above-described *B. oleracea* and *V. unguiculata* plants. The test with these plants was conducted in a greenhouse (6.1 m × 4.6 m and covered with 4-m white plastic). The greenhouse was free of other plants and insects, except for *E. pergandiella* that were released at the rate of three wasps per plant. In a circular arrangement, potted plants of each species were placed 30 cm apart on the floor of the greenhouse that lacked tables. Five plants per species were tested; they were placed so that each plant was separated by a different plant species. A 7.5 cm long clear glass vial with adult *E. perganidella* was placed in the center of the circle of plants, and one end of the vial was opened. Two hours after the parasitoids were released, the number of adult wasps observed on leaves of each plant species was recorded. Observations and data were similarly recorded at each of three subsequent 2-h intervals. The test was repeated three times.

Parasitism in the Field. Field tests were conducted on 16 crops in Egypt. The crops were established at one of five field sites; no species was grown at multiple sites. *Eretmocerus mundus* (Mercet) parasitoids were reared for five months on *B. tabaci* B-biotype on *I. batatas* in a greenhouse (5 × 3 by 3 m). The whiteflies for the parasitoids were from a research colony in Qalyubiya, Egypt, where they were reared on *Lantana camara* L. Parasitized pupal cases of *B. tabaci* were collected from the culture by brushing the pupae off leaves. The pupae were put in glass vials (15 × 3 cm), counted, and held in the laboratory at 25 ± 2°C and 65 ± 5% RH. Upon emergence of the adult parasitoids, the wasps were released (1100 to 1200 hours) into field plots for the tests. Vials containing the adult wasps were tied in a horizontal plane along the stem of the vertical midpoint of each test plant. The vials were then opened at both ends to release the parasitoids.

Eretmocerus mundus adults were released weekly into a plot of each of 16 plant species (*Beta vulgaris* L, beet, 'Giza 21'; *Brassica oleracea* variety *capitata* L., broccoli, 'Balady'; *B. oleracea* variety *botrytis* L., cabbage, 'Soltani'; *Citrullus lanatus* (Thunberg) Matsumura & Nakai ssp. *lanatus*, watermelon, 'Balady'; *Cucumis melo* L. variety *aegyptiacus* (Sickenb.) Hassib, melon, 'El-Masry'; *Cucumis sativus* L., cucumber, 'Madina'; *G. max*, 'Giza 11'; *Gossypium barbadense* L., American-Egyptian cotton, 'Giza 57'; *Helianthus annus* L., sunflower, 'Fedoak'; *I. batatas*, 'Abis'; *Lantana camara*, lantana, 'Yellow Sage'; *Lycopersicon esculentum*, 'Castel Rock'; *Phaseolus vulgaris* L., green bean, 'Broncho'; *Solanum melongena* L., eggplant, 'Aswad'; *S. tuberosum* L., potato, 'Clara'; and *V. unguiculata*, 'Fetriat') at five field locations (Beihera, Beni-Suef, Kafr Shikh, Minufiya, and Qalyubiya) in Egypt. Tests were conducted in two 35-m long × 30-m wide plots of each of the 16 plant species listed above. Weekly releases of 5 to 12 parasitoids per plant were conducted from July through October 2001, for a total of 15 releases in one plot of each crop, except parasitoid releases were made for only the first 11 wk in *G. barbadense.* The other plot of each crop, in which no parasitoids were released, was used as an untreated check within each crop. For a given crop, the treated and check plots were 75 m apart.

Thirty leaves, infested with *B. tabaci* B-biotype, were removed from each plot weekly. Plants were randomly selected in a zigzag pattern in each plot, and

the leaves were taken from the center of the selected plants. The leaves were then transferred to the laboratory. With the aid of a stereo microscope, *B. tabaci* eggs and first instar nymphs were removed as well as any other insects. The number of second, third and fourth instar *B. tabaci* per leaf was recorded. Afterwards, each leaf was stored in well-ventilated emergence glass tubes and monitored daily for parasitoid emergence. The numbers of adult parasitoids and whiteflies that emerged were recorded. The same procedure was conducted for the untreated check. Color was primarily used to distinguish between *Eretmocerus mundus* and *Encarsia lutea* (Masi) (Abd-Rabou 1998).

Data Analysis. Data were analyzed using SAS computations (SAS Institute 1999). Means were subjected to analysis of variance (ANOVA) using the general linear models procedure. Mean numbers of parasitoids per leaf or per unifoliate leaves for each plant species, each trial day, and each observation time were separated using Tukey's studentized range test. Means were transformed to normalized the data using log base 10 ($x + 1$) before analysis, but back-transformed means are presented. After arcsine transformation to normalize the data, correlation analyses were used to determine the association between the proportion of parasitoids on leaf surfaces and temperature or time of day. Also, a correlation analysis was used between temperature and time of day. The PROC MEANS procedure was used for paired comparisons between the percentages of parasitoids on the top and bottom leaf surfaces after arcsine transformation. Pairs were not used in the analysis when no insect was observed. Percent parasitism was defined as: Percent parasitism = (number of emerged parasitoids/(number of emerged parasitoids + number of whiteflies)) X 100. The PROC MEANS procedure was used for paired comparisons between percent parasitism in the check and treated plots within crops after arcsine transformation. Pairs in the data set were analyzed by sample day. Among checks within field locations, Tukey's test was used to compare means of percentage parasitism after arcsine transformation. Unless stated otherwise, differences were determined at $P < 0.05$.

Results

Parasitoid Abundance Among Plant Species. In the greenhouse, the abundance of adult parasitoids varied among seven plant species (Fig. 1). The highest number of parasitoids was observed on *V. unguiculata* followed by *G. hirsutum.* Incidence of parasitoids was similar on *C. melo*, *C. annuum*, and *G. max*, and was lowest on *L. esculentum* and *B. oleracea.* The number of parasitoids observed for a given assessment of an individual plant ranged from 0 to 71 on *V. unguiculata* and *G. hirsutum*, and from 0 to 20 on the other species of plants. Although new growth between days 1–4 was greater for some of the plant species than others, plant growth may only partly account for differences in number of wasps observed. Overall, most parasitoids ($P < 0.05$) were observed on the third and fourth days

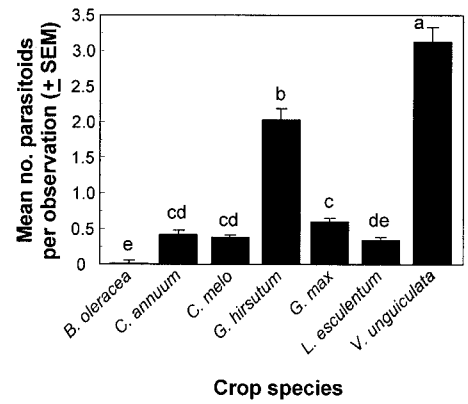

Fig. 1. Mean numbers (± SEM) of adult parasitoids (*Encarsia pergandiella*) per observation on selected leaves of seven plant species free of whitefly nymphs in a greenhouse; bars with different letters are significantly different (ANOVA, $P < 0.05$) followed by Tukey's test (SAS Institute 1999); $n = 400$ observations per plant species, except $n = 352$ for *G. hirsutum*; Genera of plants are: *Brassica*, *Capsicum*, *Cucumis*, *Gossypium*, *Glycine*, *Lycopersicon*, and *Vigna*, respectively.

of the trials and the least on the second and first days. Among plant species, the ranking of incidence of the parasitoids after adjustment for leaf area was similar (*G. hirsutum* > *V. unguiculata* > *C. annuum* > *C. melo* > *G. max* > *L. esculentum* > *B. oleracea*) as compared with total counts per plant (Fig. 1). It should be noted that counts per unit leaf area were only based on 1-d counts for each trial. A few adult parasitoids were observed alighting on some of the plants within ≈0.5 to 2 min after the test plants were transported to the greenhouse, and before the plants were placed on the table. In the dual test on *B. oleracea* and *V. unguiculata*, few parasitoids (a maximum of 17% of the released insects) were observed on the plants. Many (81%) of the observed parasitoids were found on *V. unguiculata.*

Parasitoid abundance varied between the top and bottom leaf surfaces, but was more prevalent on the bottom surface for most of the species tested (Table 1). On *V. unguiculata* and *G. hirsutum*, ≈90% of the parasitoids were found on the bottom leaf surface. Conversely, about half of the insects found on *B. oleracea* and *C. melo* were on the bottom surface. The mean number of parasitoids observed per plant species significantly increased ($P < 0.001$) from sunrise to solar noon (Fig. 2). This increase in foraging activity was observed for insects on both top and bottom leaf surfaces. However, there was a decrease in the percentage of parasitoids on the top leaf surface from sunrise to solar noon (Table 2). The percentage of parasitoids on the top leaf surface was negatively correlated with time since sunrise ($r = 0.20$; $P < 0.001$) and with temperature ($r = 0.19$; $P < 0.001$). During this experiment, temperature ranged from 18.6 to 38.0°C, averaged 28°C, and was highly correlated ($r = 0.79$; $P < 0.001$) with number of hours from sunrise to solar noon.

Table 1. Percentage of *E. pergandiella* on leaf surfaces of crop species free of whitefly nymphs in greenhouse

Crop		Percent parasitoids on leaves		*P* values (N, *t*)*
Species	Common name	Top surface	Bottom surface	
Brassica oleracea	Collard	50.0	50.0	0.132 (89; 1.52)
Capsicum annuum	Bell pepper	21.7	78.3	<0.001 (78; 4.73)
Cucumis melo	Cantaloupe	56.2	43.8	0.133 (89; 1.52)
Glycine max	Soybean	24.2	75.8	<0.001 (102; 4.44)
Gossypium hirsutum	Cotton	10.3	89.7	<0.001 (133; 11.76)
Lycopersicon esculentum	Tomato	29.2	70.8	0.466 (50; 0.73)
Vigna unguiculata	Cowpea	9.3	90.7	<0.001 (177; 11.05)

*Probability of significance, number of pairs with an observation count greater than zero, and *t* statistics for insect percentages between leaf surfaces according to Proc Means (SAS Institute 1999).

Parasitism in the Field. For each of 16 crops tested in the field, the incidence of parasitism by *E. mundus* was greater for the plot treated with released parasitoids as compared with the untreated check (Table 3). At locations with multiple crops, parasitism in the untreated checks were lowest ($P < 0.05$) for *C. lanatus* and *S. tuberosum* (Beihera site) and *C. sativus* and *C. melo* (Qalyubiya site), but all checks were the same within the Beni-Suef and Minufiya sites (Table 3). The general pattern of parasitism over time was similar for each crop for the untreated check (Fig. 3). In each crop, for both treated and untreated checks, the incidence of parasitism peaked 7 to 12 wk after the first augmentation treatment (Fig. 3). Parasitism in the treated plots of *Brassica* spp., *V. unguiculata*, and *B. vulgaris* peaked at ≈30 to 40%. The crops that seemed to have benefited most from the augmentation were: *B. oleracea* variety *capitata*, *V. unguiculata*, *C. melo*, and *G. barbadense*, while the benefit was particularly low for *C. sativus* and *L. esculentum* (Table 3). In addition, to *E. mundus*, a few other species of parasitoids, mostly *E. lutea*, were collected in the samples. Among the crops, *E. mundus* accounted for 74 to 94% of the parasitoids in the samples. Occasional individuals of *Encarsia inaron* (Walker) from *B. olearacea* variety *capitata*, *Eretmocerus corni* Haldeman from *L. camara*, *Encarsia sophia* (Girault & Dodd) from *G. barbadense*, and *Cales* sp. from *H. annus* were collected.

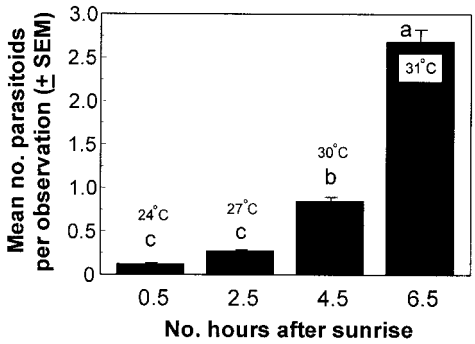

Fig. 2. Mean number (± SEM) of adult parasitoids (*Encarsia pergandiella*) per observation on selected leaves free of whitefly nymphs at various times after sunrise, averaged across seven plant species in the greenhouse; bars with different letters are significantly different (ANOVA, $P < 0.05$) followed by Tukey's test (SAS Institute 1999); mean temperature given above each bar; $n = 688$ observations per data bar.

Discussion

Our study demonstrates that parasitoid populations of *B. tabaci* can vary among crops, and that inundative release of *E. mundus* can significantly increase parasitization rates in whiteflies in numerous crops in the field. Our study did not specifically test for parasitoid attractance to the plants. Any effect of attractiveness to the plants or retention on the leaves because of the presence of any adults or eggs of *B. tabaci* that may have been oviposited during each 4-d trial is not known. However, whitefly nymphs, the stage parasitized by *E. pergandiella*, were absent during each trial. Because no eggs, nymphs, or adult whiteflies were on the plants in the dual test, this indicates that there were differences in incidence independent of the whitefly. The role of the host, *B. tabaci*, was not the subject of this study. However, based on other research (Heinz and Parrella 1998), we suspect that the presence of the host would enhance both attraction and retention of parasitoids. Our study corroborates a previous report on differing parasitoid foraging activity during the day (Simmons and McCutcheon 2001). In that study with *V. unguiculata*, *E. pergandiella* adults were observed from sunrise to sunset and most were found on leaves around mid-day. Regardless of host density, under the environmental conditions of our greenhouse experiment, the incidence of foraging should be highest around mid-day based on data herein and other research (Simmons and McCutch-

Table 2. Percentage of *E. pergandiella* on leaf surfaces of crop species free of whitefly nymphs at various times after sunrise in a greenhouse

No. of hours after sunrise	Percent parasitoids on leaves		*P* values (N, *t*)*
	Top surface	Bottom surface	
0.5	44.6	55.4	0.842 (64; 0.20)
2.5	37.0	63.0	0.036 (116; 2.12)
4.5	17.0	83.0	<0.001 (207; 7.98)
6.5	12.0	88.0	<0.001 (275; 11.09)

* Probability of significance, number of pairs with an observation count greater than zero, and *t* statistics for insect percentages between leaf surfaces according to Proc Means (SAS Institute 1999).

Table 3. List of crops, field sites, and mean (± SE) seasonal rates (during 15 wk) of parasitism of *B. tabaci* by *E. mundus* and *E. lutea* in Egypt, July–October 2001

Location	Crop			Mean no. hosts examined per week[a,b]		Seasonal mean % parasitism[a,b]	
	Family	Species	Common name	Check	Treated	Check	Treated
Beihera	Cucurbitaceae	*Citrullus lanatus*	Watermelon	136.8	189.7	3.6 ± 1.0b	28.3 ± 3.3a
	Convolvulaceae	*Ipomoea batata*	Sweetpotato	718.6	686.7	10.7 ± 2.4b	36.6 ± 4.7a
	Solanaceae	*Solanum tuberosum*	Potato	223.4	319.5	4.2 ± 1.1b	29.2 ± 2.8a
Beni-Suef	Fabaceae	*Glycine max*	Soybean	346.6	557.9	11.8 ± 2.2b	39.0 ± 4.6a
	Asteraceae	*Helianthus annus*	Sunflower	334.9	372.9	9.9 ± 2.3b	31.6 ± 3.9a
Kafr ElShikh	Chenopodiaceae	*Beta vulgaris*	Beet	273.1	357.6	9.7 ± 1.5b	36.9 ± 3.3a
Minufiya	Malvaceae	*Gossypium barbadense*	Cotton	741.5	955.5	11.5 ± 1.9b	39.2 ± 4.3a
	Solanaceae	*Lycopersicum esculentum*	Tomato	208.5	225.1	6.6 ± 1.5b	21.1 ± 2.4a
	Solanaceae	*Solanum melongena*	Eggplant	477.9	606.2	6.8 ± 1.2b	22.9 ± 2.6a
Qalyubiya	Brassicaceae	*Brassica oleracea* var. *botrytis*	Broccoli	1,397.3	1,807.9	20.3 ± 3.3b	46.7 ± 7.0a
	Brassicaceae	*Brassica oleracea* var. *capitata*	Cabbage	1,974.4	2,497.7	7.8 ± 7.9b	18.0 ± 3.1a
	Cucurbitaceae	*Cucumis melo* var. *aegyptiacus*	Melon	209.3	255.2	1.5 ± 0.5b	31.1 ± 3.1a
	Cucurbitaceae	*Cucumis sativus*	Cucumber	772.4	907.5	3.1 ± 0.9b	17.7 ± 2.3a
	Verbenaceae	*Lantana camara*	Lantana	1,947.1	2,105.7	24.6 ± 2.8b	50.8 ± 3.6a
	Fabaceae	*Phaseols vulgaris*	Green bean	1,329.0	1,319.5	11.9 ± 2.2b	37.4 ± 5.8a
	Fabaceae	*Vigna unguiculata*	Cowpea	1,414.6	1,468.2	11.6 ± 2.4b	44.8 ± 6.1a

[a] Checks' are untreated plots; 'Treated' are plots with weekly releases of *Eretmocerus mundus;* among crops, 74 to 94% of the parasitoids were *E. mundus.*

[b] Means in a row and followed by different letters are significantly different ($P < 0.0001$) according to t statistics using Proc Means (SAS Institute 1999).

eon 2001). In another field study, plant species were among factors which affected the abundance of parasitoids in three vegetable crops (Simmons and Jackson 2000), and parasitoids were captured from newly emerged *V. unguiculata* plants before whitefly nymphs were present in the field (A.M.S. unpublished data).

In laboratory studies with several species of whitefly parasitoids on *G. hirsutum* and *Euphoria pulcherrima* Willd. ex Klotzsch, poinsettia, Heinz and Parrella (1998) reported an attraction to the odor of detached whitefly-infested leaves by *E. pergandiella* (California strain) in an olfactometer, and by some *Encarsia* and *Eretmocerus* species and strains, but not others. They further reported that parasitoids were attracted toward whitefly nymphs in an olfactometer, and that there was a difference in attraction to the two plant species. They noted that previous researchers testing *Encarsia formosa* Gahn in olfactometers, did not observe any plant odor or host recognition. Many other parasitoid species have been shown to orient toward plant volatiles (e.g., Martin et al. 1990, Whitman and Eller 1990, Kester and Barbosa 1994, Whitman and Nordlund 1994, Geervliet et al. 1996). Leaves which are insect or mechanically damaged are more likely to elicit a response from some parasitoids compared with undamaged leaves, such as used in our greenhouse experiment. Plants of newly emerged crops would be undamaged. It would be useful for parasitoids to discriminate among host plants and nonhost plants of phytophagous insects, otherwise, foraging time may be ineffective. However, the presence of the host on the plants may help to enhance the recognition of a plant species by the parasitoid.

The change in parasitoid abundance on the plants from sunrise to mid-day indicates a high rate of interplant movement. Because only a few parasitoids were on the plants at sunrise, the incidence of overnight resting on the plants may have been low. In a laboratory study with whitefly nymphs on leaves, Headrick et al. (1996) reported that *Eretmocerus* sp. spent ≈59% of its time host feeding, grooming, and resting. In other laboratory work, Headrick et al. (1995), reported that *Eretmocerus* sp. nr. *californicus* Howard spent more time searching on whitefly nymph-infested leaves of *G. hirsutum* than on infested *C. melo.* Plants used in our study represent diverse taxonomic species. Specific reasons for variable parasitoid foraging may include physical factors such as plant color and plant texture (Price 1986). In our tests, however, abundance was not affected by phenotypes. For example, no trend was observed for parasitoid abundance whether crops had prostrate or upright growing habits, or whether the leaves were pubescent or glabrous. A preliminary greenhouse test using unifoliate leaf stage *V. unguiculata* and first trifoliate stage *V. unguiculata* without unifoliate leaves, resulted in similar number of parasitoids even though they differed in height.

It is useful for the parasitoids to forage on both surfaces of host plants because whitefly nymphs feed and develop on both surfaces of many plant species (Simmons 1994, 1999, Simmons et al. 2000). However, most whiteflies develop on the lower leaf surface of most host species including the species in this study (van Lenteren and Noldus 1990, Lynch and Simmons 1993, Simmons 1994, 1999). Hence, foraging time may be less efficient on *C. melo* and *Brassica* where a relatively high percentage of parasitoids were observed on the top leaf surface (Table 1).

Whiteflies infest cropping systems regardless of plant abundance, whether the crop is in an open field, greenhouse, or backyard. Likewise, the density of whiteflies in cropping systems is highly variable. Host plant species can affect the abundance of whiteflies as well as parasitoid abundance and rate of parasitism.

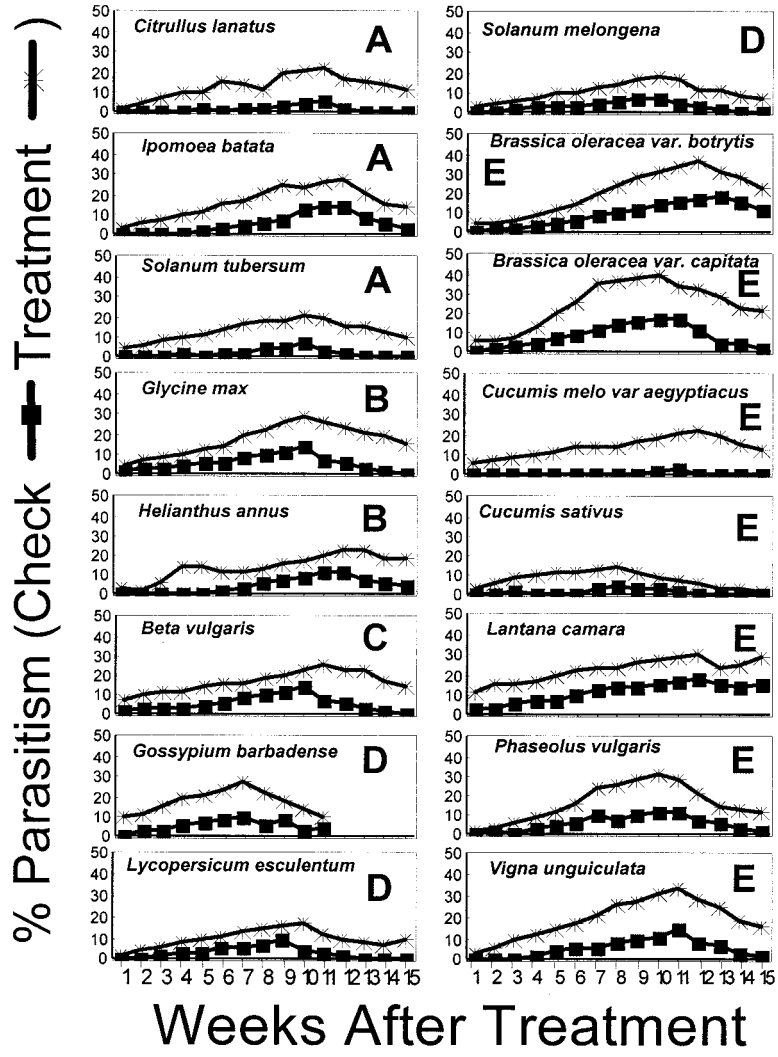

Fig. 3. Mean percent parasitism of *Bemisia tabaci* for crops in field plots without (check) and with (treatment) augmentation using *Eretmocerus mundus*, 2001; Locations are: A, Beihera; B, Beni-Suef; C, Kafr ElShikh; D, Minufiya; and E, Qalyubiya in Egypt.

Factors such as temperature (Simmons and McCutcheon 2001) and time of day can also affect parasitoid foraging activity. These findings help in the understanding of the behavior and ecology of whitefly associated parasitoids, and in the assessment of the roles of plant species in whitefly management schemes.

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